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MACBETH ILLUMINOMETER

BULLETIN No. 680
1925

LEEDS & NORTHRUP COMPANY

ELECTRICAL MEASURING INSTRUMENTS

4901 STENTON AVE. PHILADELPHIA, PA.

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CONTENTS

INTRODUCTION

The Macbeth Illuminometer was developed by the Leeds & Northrup Company in conjunction with Mr. Norman Macbeth, consulting illuminating engineer.

This illuminometer differs from all others in that it includes a reference standard against which the illuminometer may be checked at any time. In making this check, there is no need for a dark room or any auxiliary photometric apparatus. By the use of the reference standard, personal errors are eliminated, for each observer makes his own calibration of the illuminometer.

The convenience and compactness of the Macbeth Illuminometer have resulted in its adoption as a part of other photometric instruments. A recent example of this is the adoption of the Macbeth Illuminometer for use with the Absolute Reflectometer, developed at the U. S. Bureau of Standards by Mr. A. H. Taylor. See N. B. S. Scientific Paper No. 405.

Fig. 1. MACBETH ILLUMINOMETER
(Patented Jan. 8, 1918)

USES OF THE MACBETH ILLUMINOMETER

The Macbeth Illuminometer differs from the ordinary photometer only in the details of its construction and in that its scale is calibrated to read in foot-candles. The method of its use is also somewhat different, as will be explained later.

Measurement of Intensity of Illumination

In using the Illuminometer to measure illumination intensities a test plate is placed at the point in the plane where the illumination value is desired. This test plate is made of a white material of good diffusing qualities. Care has been used in the selection of this plate to insure, as far as possible, its coefficient of reflection being constant for all angles of incident light. The test plate becomes a secondary source of light, the brightness of which is compared with that of a translucent screen within the instrument which is illuminated to a known intensity by a small Mazda lamp. The scale of the instrument is calibrated in foot-candles, and when standardized it allows for the absorption of the test plate; hence the device is direct reading and the values secured give the intensity of illumination on a given surface.

Measurement of Brightness

In measuring brightness a separate standardization is made, taking into consideration the absorption of the test plate. This value is in terms of "apparent foot-candles" emitted and usually renders the brightness of sources or surfaces direct reading from the same scale on the instrument without the use of factors for multiplying or dividing the scale values excepting where results are desired in terms of candle-power per square inch, square foot, square centimeter or square meter.

Measurement of Intensity of a Source

The intensity of any source of illumination may be determined by placing the test plate a known distance from the source, measuring the illumination intensity in foot-candles upon the test plate and then computing the candle-power by multiplying the scale values by the square of the distance of the test plate from the unknown source (the law of inverse squares).

SUMMARY OF FEATURES

Attention is called to the following important points in connection with the Macbeth Illuminometer.

1. The scale follows the inverse square law and is theoretically correct and not experimentally determined for each instrument.

2. A Lummer-Brodhun cube is used, as it is more sensitive than any other type of screen and permits a quicker and more accurate balance. The prisms are so arranged that a circular field, and not the usual elliptical field, is seen when looking through the telescope. All optical parts may be readily removed for cleaning.

3. A direct and simple means is provided for standardizing the Mazda working standard lamp within the instrument. Thus the user calibrates the instrument for himself, when and where he pleases, and does not depend upon the factory calibration.

It is well known that a large personal element enters into the reading of a photometer. This "personal equation" is practically eliminated in the Macbeth Illuminometer as every user calibrates his own instrument and does not have to use a calibration which may have been correct for the person who calibrated the instrument in the laboratory, but probably is not correct for him.

4. Every effort has been made to co-ordinate properly the qualities of compactness, light weight, accuracy, completeness and cost.

GENERAL DESCRIPTION

Fig. 2. Illuminometer (1/5 actual size)

The Macbeth Illuminometer consists of three main parts and various accessories, all contained in a convenient leather carrying case measuring 10 x 17 x 6¾ inches and weighing, complete, 14 pounds, with all parts in place excepting the battery. The battery may weigh from 1½ to 4 pounds, depending upon the kind and size of cells used.

The three main parts are the Illuminometer, the Controller and the Reference Standard.

THE ILLUMINOMETER

The Illuminometer, together with the other elements of the equipment is shown in Fig. 1, and separately in Fig. 2. A Lummer-Brodhun cube is mounted in the rectangular head. By removing the head from the tube and then taking out two screws the cube may be removed for cleaning. It is quite easily replaced, it being impossible to return it to a wrong position. The photometric field is viewed through the telescope. The aperture opposite the telescope is aimed or pointed toward the test plate, or any surface of which the brightness is to be measured. In the tube, which is 9 inches long by 1¾ inches in diameter, is a diaphragmed carriage within which is mounted an electric incandescent lamp which will hereafter be called the working standard. The lamp carriage is moved up and down in the tube by means of a substantial rack and pinion operating upon a square brass rod to which the carriage is fastened. This rod is seen projecting from the bottom of the tube (Figs. 2 and 3). In this connection it is important to note that the control of the travel of the working standard is positive. All parts involved are metal. On one side of the rod to which the lamp carriage is attached is engraved the direct reading scale calibrated from 1 to 25 foot-candles. An index point is attached to the bottom of the tube. As will be

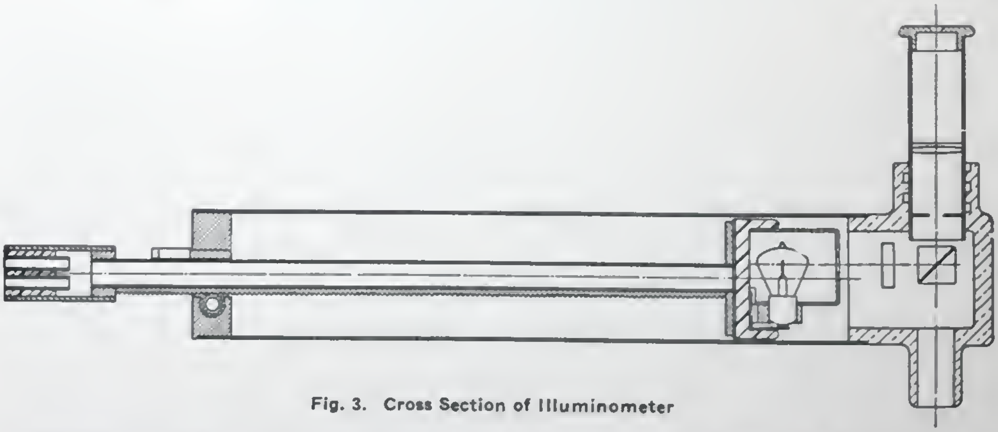

Fig. 3. Cross Section of Illuminometer

explained later, this index mark is adjustable to allow for variations in filament position of different working standard lamps. Special attention has been given to the elimination of reflection in the interior of the tube. That this has been successfully done is attested by the fact that the scale follows the inverse square law. The illuminometer weighs 20 ounces.

THE CONTROLLER

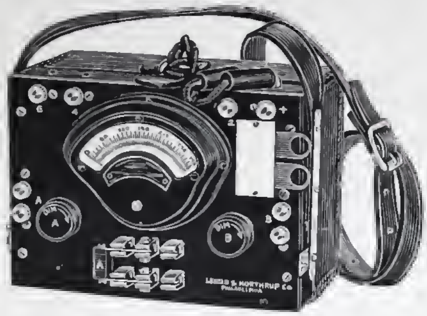

Fig. 4. Controller (1/5 actual size)

The second unit of the equipment is the Controller. It is supplied with a shoulder strap for convenience of operation and observation when using the instrument. The controller comprises the battery for operating the lamps, a Weston mil-ammeter, two close regulating rheostats, one for the working standard and one for the reference standard lamp, hereafter called the Reference Standard, and a double-throw switch, by means of which the mil-ammeter may be brought into either the working standard circuit or the reference standard circuit. All these parts are mounted upon a hard-rubber plate, which is in turn mounted upon a hardwood base. The controller is shown in Fig. 4. Around the edges of the wooden base are six plug connectors; one of these is for the attachment of the working standard, a second for the attachment of the reference standard, and the four remaining ones for battery connections. The equipment is ordinarily operated from two No. 6 dry cells in series, carried in the leather case fastened to the under part of the controller. When the mil-ammeter is thrown from one circuit to the other a resistance is automatically thrown in the circuit from which the mil-ammeter has been removed, this resistance being just equal to the resistance of the mil-ammeter, thus avoiding a change of current through either lamp. The diagram of connections of the controller is shown in Fig. 5.

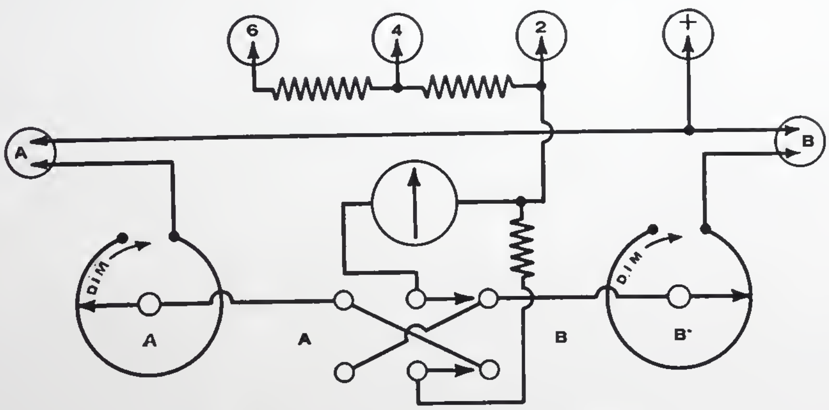

Fig. 5. Diagram of Connections of Controller

By using a mil-ammeter instead of a voltmeter for the control of the lamps, there is no liability of error due to changes in contact resistances, the breaking of strands in the flexible cords, and other possible sources of difficulty. All flexible cord ends are made up with set screw connections so that new cords may be substituted without trouble.

THE REFERENCE STANDARD

Fig. 6. Reference Standard (1/4 actual size)

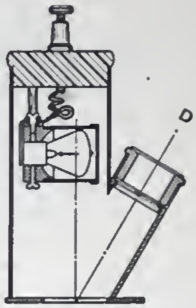

Fig. 7. Cross Section of Reference Standard

In the third element, or Reference Standard, is presented a decided improvement in illuminometer design. It is illustrated in Fig. 6. A cross section is shown in Fig. 7. By the use of the Reference Standard, the illuminometer may be checked at any time or place, doing away with the necessity of a dark room and auxiliary photometric apparatus and with the inconvenience and expense of laboratory standardized working standard lamps. The ease of frequent calibration permits the use of working standard lamps at a very much higher efficiency than ever attempted before, thus securing better color of light and considerably reducing the current demand and consequent battery capacity.

The elimination of the personal factor which is always present when using illuminometers standardized by others is of the greatest importance. In the Macbeth Illuminometer each operator standardizes the illuminometer against an exact known illumination intensity and thus compensates for the personal difference of various photometric observers.

The Reference Standard consists of a metal housing in which is mounted a standardized lamp, fully protected with diaphragm screens. The interior parts, after standardization, can be effectively sealed. The lamp used is seasoned and is run at such low efficiency and for such short times as to insure the greatest possible constancy.

The construction of the Reference Standard is shown in Fig. 7. In using this element it is placed upon the test plate so that the plate is illuminated by the standardized lamp through the opening C. Before leaving the factory the Reference Standard lamp is so seasoned and calibrated that when a current of the value given in the accompanying certificate is passed through the lamp there will be a definite intensity of illumination upon the test plate. The illuminometer may then be calibrated by placing the sighting aperture into the hole marked D and adjusting the current through the working standard.

ACCESSORY APPARATUS

Test Plate

An extensive series of tests was carried out to determine the best material to use for the test plate. In the selection of this material a number of points were considered. In the use of all ordinary test plates errors are invariably introduced as the angle of incidence of the light upon the test plate, or the angle of emergence from the test plate to the illuminometer, becomes greater with respect to a line normal to the plate. The character of the test plate should be such that its coefficient of reflection is as nearly as possible independent of the angle of incidence of the light falling upon it or the position from which it is observed. With a given illumination a perfect plate would be of equal brightness when viewed from all directions. Such a surface has never been secured. An important advance, however, has been made beyond previous practice. It was

ACCESSORY APPARATUS (Continued)

TEST PLATE (Continued)

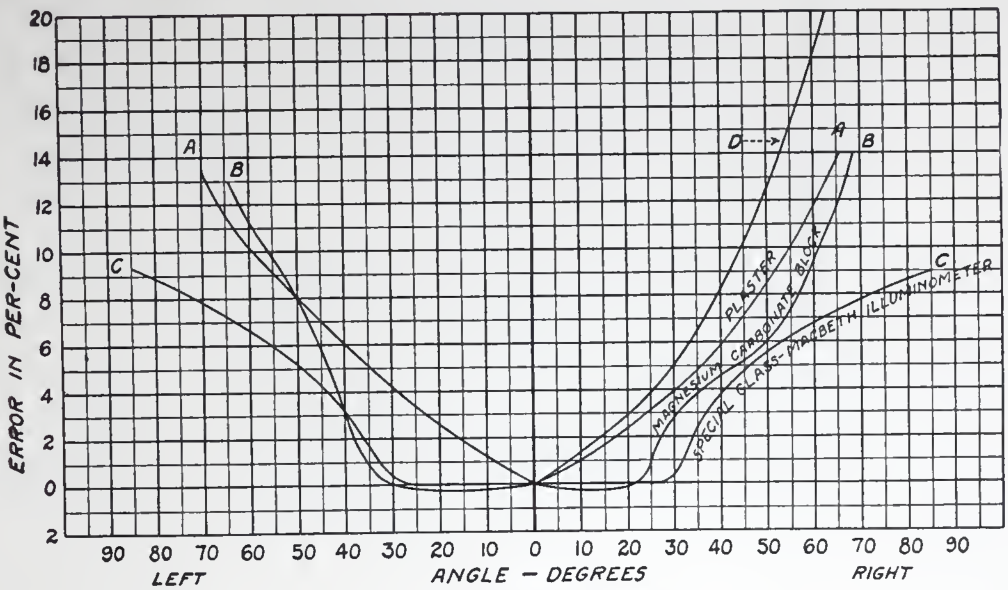

Fig. 8. Test Plate Curves

found that the reflecting characteristics of surfaces varied with different materials and also with different surface conditions of the same material. Fig. 8 shows curves of three different materials from among a large number tested, and also the ordinary plate heretofore in use and tested by Edwards & Harrison.*

Curve A represents the results obtained from a surface of plaster. At an angle of incidence of 20° there is an error amounting to over 2 per cent. Curve B represents the results from block magnesium carbonate. This material is good up to an angle of 20° but poor beyond that point. Further it is not a practical material to use for test plates. Curve D is taken from the paper of Edwards & Harrison referred to above. Curve C, representing the material adopted for the test plate, shows practically no error up to an angle of 25° and from that point the error is much less than the other materials indicated.

The plates furnished are of glass finished by a special process These plates may, if care is used, be washed with soap and water without any danger of changing the character of the surface.

SCREENS

The scale of the illuminometer is from 1 to 25 foot-candles. In order to increase the range of measurement, absorbing screens are provided. These screens are made of Wratten filters which may be placed one side or the other of the Lummer-Brodhun cube, thus widely extending the normal range of the instrument. Screens of various densities may be used, either neutral or colored, for selective absorption. These screens are very easily inserted or removed. The total range of the instrument with the two screens ordinarily provided is from about .02 to 1200 foot-candles, but this range may be extended by additional screens, two or three thousand times maximum and minimum, if desired.

*Trans. Ill. Eng. Soc.; Vol. 8, P. 642.

ACCESSORY APPARATUS (Continued)

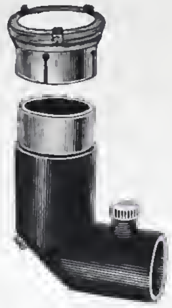

Fig. 10. Horn and Translucent Test Plate 1/3 actual size

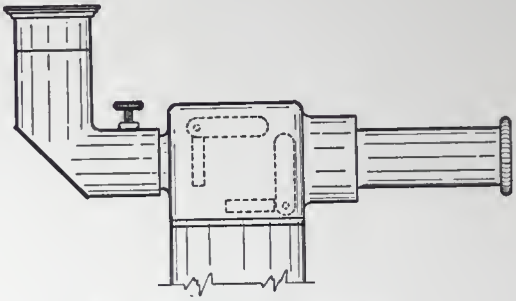

Fig. 11. Showing Horn Attached to Illuminometer

SCREENS (Continued)

Special screens of low absorption, which may be used together with any of the neutral absorbing screens, are available for use in making measurements of daylight, etc., producing a good color match. These screens overcome the difficulty which has always been experienced in making illumination measurements when the color of the light under test differs greatly from that of working standard lamps.

TRIPOD

A light weight, easily adjusted tripod is provided for holding the test plate in any desired position from horizontal to vertical, and at various heights. In passing it may be noted that in this tripod there are no set screws to lose, as all parts are held together by friction clamps.

HORN

In making brightness measurements on ceilings or other high surfaces it is convenient to use an attachment which provides for holding the illuminometer in a comfortable position while viewing these surfaces. This attachment consists of a light weight metal elbow or horn with screening diaphragms and a mirror set at an angle of 45 degrees. This horn may be slipped over the illuminometer viewing tube. See Fig. 11. When using the horn, a comparison with the Reference Standard must be made with the horn in place to take into account the absorption of light by the mirror.

In most illuminometers now on the market the light to be measured is received on a small test plate fastened upon the illuminometer. When measurements are being made at, say, a 30-inch height this necessitates a rather cramped tiring position of the operator when reading the illuminometer. With the Macbeth Illuminometer as ordinarily used, that is, placing the test plate in the plane where measurements are being made, the operator can stand upright in a normal position when making tests. If, however, he should desire to make measurements in the old way, a cap for mounting on the horn and carrying a small translucent test plate is furnished with the equipment. When using the small test plate the standardization should be made with this test plate. This is accomplished by placing the reference standard on top of the small test plate. Provision is made for holding the reference standard in this position during standardization.

TRIPOD ATTACHMENT

This is an attachment provided for holding the illuminometer in a horizontal position on the tripod when it is desired to use the instrument for making illumination measurements with the horn and translucent test plate at the 30-inch height.

PRICE LIST

No. 6800. Macbeth Illuminometer (1/6 actual size)

6800	**MACBETH ILLUMINOMETER, Complete**..................	$210.00
	Includes Illuminometer, Controller, Reference Standard, Tripod, two Absorbing Screens (range about .02 to 1200), Test Plate, Horn with Translucent Test Plate, two extra Working Standard Lamps and Carrying Case.	
6810	**Illuminometer** only..	$100.00
6812	**Controller**..	80.00
6814	**Reference Standard**..	30.00
6816	**Tripod**..	5.00
6818	**Absorbing Screens**, each.....................................	5.00
6820	**Test Plate**..	7.00
6822	**Horn**, including Translucent Test Plate......................	15.00
6824	**Color Filter**, for Daylight Determinations..................	9.00
6826	**Additional Working Standard Lamp**............................	3.00
6830	**Clamp** for fastening Illuminometer to Tripod.................	3.00
6832	**Carrying Case**...	25.00
	Restandardization Fee for Reference Standard...............	5.00
	Restandardization Fee for Reference Standard, furnishing new lamp..	12.50

The charge for certification by the Electrical Testing Laboratories, of all parts which require certification, is included in the prices given above.

DIRECTIONS FOR OPERATING

General

In using the Macbeth Illuminometer the controller is slung over the shoulder of the operator and placed in any convenient position in front of him or at his side, so long as the mil-ammeter is plainly visible. If there are several observations to be made an assistant may carry the controller, or it may be set upon a table or other support. If dry cells are to be used, two No. 6 cells, connected in series, may be placed in the leather pocket under the controller. Connect the battery to the leads provided. On the outer ends of these leads are plug connectors. The one marked + should be placed in the receptacle marked +. The one marked — should be connected to the receptacle marked 2. Small, light weight, portable storage cells, such as the Porox, may be substituted if desired. If external batteries are being used they should be connected by means of the flexible cords to the proper receptacles in the controller. For instance, if an outside battery of three storage cells in series were used, it should be connected to the receptacles marked + and 6, since the battery will have an e.m.f. of about six volts. As the e.m.f. of the battery falls the plug may be inserted in the next lower receptacle. As a precaution, it is advised that in all cases where the battery voltage is unknown the battery be connected first in the six-volt receptacle, and later changed, if necessary. In no case should more than six volts be applied to the controller.

Before the Illuminometer or Reference Standard can be connected both rheostat handles must be turned in the direction of the arrows toward "Dim" as far as they will go. This important preventive of carelessness cuts in resistance in the two lamp circuits and prevents passing too much current through the lamps. Connect the Reference Standard to the receptacle marked A and the Illuminometer to the receptacle marked B, using the flexible cords provided for this purpose. Place the Reference Standard upon the test plate and throw the double-throw switch on the controller in the direction of A. Turn the rheostat A in the direction opposite to that indicated by the arrow, until the reading of the mil-ammeter corresponds to the current value on the Reference Standard certificate.

There is now an illumination upon the test plate corresponding to the value given in the certificate. Now set the illuminometer scale to that value. Throw the double-throw switch to B and, placing the sighting aperture of the illuminometer into the hole D (Fig. 7) of the Reference Standard, adjust the current through the working standard by turning rheostat B up and down until a balance is secured. When this balance is obtained note the mil-ammeter reading on the working standard. Now throw back the double-throw switch to the position A to see that the current through the Reference Standard has not changed. In each case take several settings in order to obtain average values. In actual use the working standard current is to be kept at the value determined by this check test. To do this keep the double-throw switch in the position B and alter the setting with rheostat B whenever the current changes. The reference lamp should be disconnected as soon as the working standard has been calibrated. It is important that the Reference Standard be used as little as possible in order that its calibration may be retained over a long period.

Measurement of Illumination

In using the illuminometer grasp the tube in one hand, holding the telescope to the eye, and with the other hand operate either the right- or left-hand knurled head which, moving the working standard, increases or decreases the brightness of the outer concentric field of the photometric screen. Assuming that the illuminometer has been calibrated, place the test plate at the point in the plane (horizontal or inclined) where a measurement is desired.

DIRECTIONS FOR OPERATING (Continued)

The plate may be placed upon a desk, table, etc., or it may be attached to the tripod and be readily moved about to the various stations desired. The distance of the observer from the test plate will not introduce any error so long as the inner field of the Lummer-Brodhun cube is completely illuminated, or in other words, the distance between the illuminometer and the test plate is immaterial provided the distance is not so great that the surroundings of the test plate appear on the inner field of the Lummer-Brodhun cube. If the proper maximum distance is exceeded it can be readily detected, provided the test plate is not set upon a white surface, by the non-uniform illumination of the inner field. The safe maximum distance will be between 6 and 8 feet

When making measurements the angle between the axis of the telescope and sighting aperture and the normal to the test plate should not exceed 30° to 40°. With the equality of brightness type of Lummer-Brodhun screen when looking through the telescope there will be seen two concentric fields. The outer one is illuminated by the working standard, and the inner by the test plate, or other surface, the illumination upon which is to be determined. View the test plate through the telescope, turning the knurled handle on the lower end to shift the working standard nearer to or away from the prism until a balance is secured, i. e., until the outer circle matches in brightness the inner circle illuminated by the test plate. If the surface under observation is of exactly the same color as the light from the working standard the line of demarkation between the two fields will disappear, when a balance is obtained. If there is a color difference it will be impossible to obtain this disappearance. In that event to obtain a balance judgment is required as to when the two fields are of equal brightness. This is a matter of experience and is very quickly learned.

For those who prefer a translucent test plate viewed from beneath instead of the usual opaque test plate furnished with the illuminometer, a removable cap carrying a translucent plate is furnished, which is slipped over the horn. A new current value will be required for the working standard. For use in the determination of this value there is provided an attachment whereby the small translucent disc on the horn is attached to the bottom of the Reference Standard in such a manner that it receives the proper illumination from the Reference Standard lamp.

Use of Absorption Screens

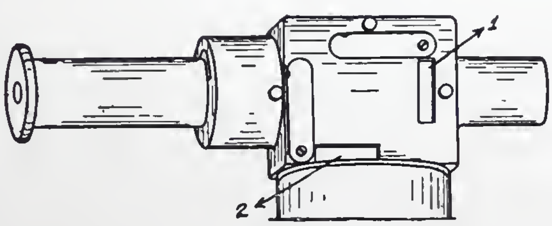

Fig. 11
Sighting Head of Illuminometer

When the intensity observed is too high or too low to be read directly on the scale of the illuminometer, it is necessary to use the absorbing screens provided with the equipment. If the intensity observed is too high the proper screen should be placed in Slot 1 shown in Fig. 11. If too low the screen should be placed in Slot 2. When using a screen in Slot 1 the scale reading should be multiplied by the factor given in the certificate for the screen. If the screen is in Slot 2 multiply the scale reading by transmission value given in the certificate.

DIRECTIONS FOR OPERATING (Continued)

Screens for Great Color Differences

In making measurements under such conditions that a great color difference exists between the two concentric fields of the Lummer-Brodhun cube, such, for instance, as daylight measurements, etc., special screens are provided for producing a color match. When using these screens factors must be used in interpreting the results. Each screen has its factor certified, but these factors hold only for the particular color of illumination for which the screen is intended.

Brightness Measurements

Brightness measurements in "apparent foot-candles" are made in a manner similar to illumination measurements, excepting that neither the test plate nor the translucent disc is used and the values secured either must be multiplied by the coefficient of reflection of the test plate with which the standardization has been made, or a separate standardization must be made, based on the "apparent foot-candles" emitted from the test plate in accordance with the value noted in the certificate.

If it is desired to reduce these readings to values in units of candle-power per square foot, divide by π or 3.14; for candle-power per square inch divide by 452 (3.14 x 144); per square centimeter by 2920 (3.14 x 929); per square meter by .292 (3.14 x .0929).

The diameter of the field of observation is roughly one-tenth of the distance between the observer and the surface being observed. At 30 feet the diameter of the field is 3 feet.

Measurement of Candle-Power

To determine the candle-power of a lamp or any light source, set up the test plate in a plane normal to a line from the light source to the test plate, and at a measured distance away from the unknown source. Arrange suitable screens to cut off all light from the test plate except that coming directly from the source under test, or make the measurement in a dark room. Measure the illumination upon the test plate in the manner previously described. The value in foot-candles when multiplied by the square of the distance in feet from the test plate to the lamp will give the candle-power in that direction. Vertical distribution curves may be obtained from lamps by rotating them around a horizontal axis through the lamp center, or if the lamp cannot be rotated, by fastening the test plate upon an arm which may be rotated vertically about the lamp as a center. In all cases care should be taken that the light falls normally on the test plate and that the test plate is viewed through the illuminometer within the 30° zone normal to the test plate.

To Replace the Working Standard Lamp

Remove the three screws holding the bottom cap of the illuminometer and withdraw the rack and lamp housing from the tube. Remove the cover on the lamp housing, and by loosening the screw in the socket clamp, the lamp may be removed. Insert the new lamp. See that the plane of the filament is parallel to the plane of the base supporting the socket. Replace the lamp housing and then the cap carrying the rack. Connect the lamp in circuit with sufficient resistance in series to bring the filament to a dull red. Holding the illuminometer vertical, sight through the two slits near the bottom of the tube and adjust the rack up and down until the center of the filament is in line with the centers of the slits.

Now examine the scale and index. If the index mark is not in exact line with the special mark on the scale loosen the screw holding the index plate and move the plate until the two marks coincide. This renders the scale direct reading throughout its entire range for the new lamp.

Recalibration of Reference Standard

This should be attempted only in a laboratory where excellent facilities are available. The Reference Standard may be returned to the factory or to the Electrical Testing Laboratories for careful standardization at a nominal fee.

PHOTOMETRIC DEFINITIONS

CANDLE-POWER

In the use of the illuminometer some brief explanation of photometric terms may be helpful. The candle-power is the unit in which the intensity of a source of light in any one direction is measured. The value was originally derived from the amount of light given by a sperm candle burning under certain fixed conditions, but has now been standardized so that it is an international unit.

FOOT-CANDLE

The foot-candle is the unit of illumination intensity, and is that intensity at a point on a surface one foot distant from a source of one candle-power. This intensity varies inversely as the square of the distance of the surface from the source. A point two feet from a one-candle-power source would receive an illumination of $(\frac{1}{2})^2$ or 0.25 foot-candle.

LUMEN

The lumen is the unit of luminous flux or emanation of light from a source, and is that quantity of light which will produce a normal illumination of one foot-candle over a surface of one square foot.

MEAN SPHERICAL CANDLE-POWER

A source of one mean spherical candle-power at a distance of one foot from a surface normal to the incident light will deliver at all points on that surface an intensity of one foot-candle. A sphere of one foot radius with a one spherical candle-power source at its center will receive an incident illumination of one foot-candle at all points over its inner surface. The area of a sphere of one foot radius is 12.57 square feet. The quantity of light emitted is therefore equal to the intensity at the surface (1 foot-candle per square foot = 1 lumen) multiplied by the area of the sphere (12.57 square feet) or, quantity of light = 1 x 12.57 = 12.57 lumens. If the light source does not emit equal amounts of light in all directions the average is obtained and is known as the mean spherical candle-power. One mean spherical candle-power equals 12.57 lumens.

BRIGHTNESS

Brightness—termed also "intrinsic brilliancy" and "surface brightness"—refers to the appearance of a light reflecting surface or a light source when viewed from a particular direction. By sanction of the Illuminating Engineering Society* and adopted by the American Institute of Electrical Engineers, brightness is expressed in terms of candle-power per unit area. For brightness of a high order it is usually stated in candle-power per square inch or per square centimeter, although for reflecting surfaces of a lower order of brightness candle-power per square foot or per square meter has been found to result in more appreciable values.

APPARENT FOOT-CANDLE

The brightness in "apparent foot-candles" emitted from a source or surface, if distributing light uniformly in all directions, as from a hemispherical source or from a perfectly mat surface, when divided by π (3.14) gives candle-power per square foot.

While "foot-candles," as ordinarily used, refers to the flux density received on a plane, "apparent foot-candles" may be used conveniently to express brightness** with the understanding that "one foot-candle of brightness would be identical in appearance to (a) that produced by an illumination of one foot-candle upon a perfectly mat diffusing and reflecting surface of 100 per cent reflecting power, or (b) that of a surface source of light emitting at a density of one lumen per square foot, such flux being emitted in accordance with the cosine law."

"Apparent foot-candles" becomes at once a convenient term differing actually from the foot-candle value incident on a plane or surface, by the absorption of that surface. A surface with five foot-candles incident would have an absorption of 20 per cent if the emitted light or brightness in a given direction was four "apparent foot-candles."

*Trans. I. E. S. Vol. VII, P. 728.
**J. R. Cravath, Elec. World, Dec. 12. 1914. P. 1157.

LEEDS & NORTHRUP PUBLICATIONS

The following catalogs and bulletins are listed to aid anyone interested to obtain information about apparatus and instruments manufactured by this company.

Any of these publications will be sent upon request.

CATALOGS

No.	Date of issue	
10	1925	Apparatus for Capacitance, Inductance and Magnetic Measurements.
20	1923	Galvanometers.
*30	——	Keys and Switches for Electrical Testing.
40	1923	Resistance standards, Resistance Boxes.
48	1924	Apparatus for Measuring Conductivity of Electrolytes.
50	1923	Portable Testing Sets and Cable Testing Apparatus.
*60	——	Photometric Apparatus.
75	1924	Apparatus for Electrometric Determination of Hydrogen Ion Concentration.
**80	——	Electrical Resistance Thermometers.
86-B	1919	The Optical Pyrometer.
87	1924	Potentiometer Pyrometers.
90	1924	The Hump Method for Heat Treatment of Steel.

BULLETINS

No.	Date of issue	
235	1924	The Vibration Galvanometer.
429	1921	Kelvin Bridge Ohmmeter.
434	1921	Students' Kelvin Bridge.
533	1925	The Burrows Permeameter—The Epstein Core Loss Apparatus.
536	1921	Bridge for Locating Faults in Power Circuits.
541	1921	Type T Testing Set.
650	1915	Double Arm Exploring Mirror.
680	1925	Macbeth Illuminometer.
715	1925	Silsbee Current Transformer Testing Set.
716	1923	Potential Transformer Testing Set.
726	1920	The White Potentiometer.
755	1923	The Type K Potentiometer.
763	1923	The Brooks Model 7 Deflection Potentiometer.
765	1920	Students' Potentiometer.
766	1923	Laboratory Hydrogen Ion Potentiometer.
767	1923	Bovie Hydrogen Ion Potentiometer.
857	1920	Automatic Temperature Control.
865	1921	Wall Type Potentiometer Indicator.
866	1916	Apparatus for the Location of Thermal Transformation Points.
871	1925	Temperature Measurements in Generators, Transformers and Cable Systems.
872	1923	Flue Gas Temperatures, Potentiometer Pyrometers.
980	1924	The Synchronizing Fork.
984	1925	The Vreeland Oscillator.

* Being revised.

** Temporarily out of print.

Printed in U. S. A.